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LLOYD B. SHERROD
YUSUF N. TAMIMI
STANLEY M. ISHIZAKI

Hawaii Agricultural Experiment Station, University of Hawaii

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AUTHORS

LLOYD B. SHERROD was Assistant Animal Scientist at the Hawaii Agricultural Experiment Station, Hilo.

YUSUF N. TAMIMI is Assistant Agronomist at the Hawaii Agricultural Experiment Station, Hilo.

STANLEY M. ISHIZAKI is Junior Analyst at the Hawaii Agricultural Experiment Station, Hilo.

Effects of Stage of Maturity Upon Yield, Composition, and Nutritive Value Of Whole Plant Corn and Forage Sorghum[1]

LLOYD B. SHERROD, YUSUF N. TAMIMI, and STANLEY M. ISHIZAKI

Forages are the major feed source in most phases of production for the beef cattle industry in Hawaii. Forage crops such as corn and sorghum offer great potential both for increasing total forage production per acre and flexibility of utilization, since they can be fed either as green chop or ensiled. The use of intensively grown forage crops in beef production programs could provide means for increasing total beef production. It could also improve the sub-optimal rate of post-weaning performance that is frequently observed in growing beef cattle grazing only unimproved pastures. In addition, forage crops might be utilized in conjunction with concentrate feeds during certain periods of the fattening phase of production.

Most research concerning the nutritive value of forage crops has been conducted in temperate regions. Additional information is needed regarding the nutritive value of these forages produced in subtropical climates. This study was conducted to investigate the effects of stage of maturity upon yield, composition and nutritive value of whole plant corn and forage sorghum grown under high-rainfall, subtropical conditions.

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[1]This study was conducted in cooperation with Western Regional Project W-94, Range Livestock Nutrition.

Experimental Procedure

Hybrid corn (Funk G-6999)[2] and forage sorghum (Hay Grazer)[2] were planted on newly cleared land at the Waiakea Experiment Station. The land on this station is dominated by broken lava rock (*aa*) on the surface with some sub-surface fine soil material. Twelve 15 x 45-foot plots of corn and of sorghum were planted with four replications for each of three stages of maturity. The 12 plots were randomized within adjoining areas for each crop. The corn was planted with 9-inch spacing between hills and the sorghum drilled in five rows per plot with 3-foot spacing between rows. Initial fertilizer applications for both crops were equivalent to 150 pounds N, 250 pounds P, and 200 pounds K per acre with an additional 150 pounds N and 15 pounds Zn applied one month after planting. Subsequent applications of fertilizer on the sorghum plots were 20 pounds N, 22 pounds P and 23 pounds K after each 13.74 inches of rainfall during a period of one year. This brought the total fertilizer for sorghum during the year to 440 pounds N, 407 pounds P and 362 pounds K per acre.

Both forages were harvested at three stages of maturity determined by the maturity of the seed portion of the plant. The stages of maturity were silk (I), milk (II) and early dent (III), and heading (I), milk (II) and dough (III) for the corn and sorghum, respectively. In the case of the sorghum, ratoon growth was allowed to continue after each previous cutting. The three stages of maturity in the ratoon crops were harvested from the same plots which had previously produced each respective stage of maturity.

The middle three rows of each plot were harvested to determine yield. Plant samples from the three harvested rows were collected for moisture determination and tissue analysis. Total nitrogen was determined by the Kjeldahl procedure. Plant tissue samples were ashed and phosphorus and potassium determined by phosphomolybdic blue and flame photometry methods, respectively. The versenate method was used to determine calcium and magnesium.

Digestibility was determined using samples composited from all replications in each stage of maturity of the corn and the original and first ratoon growth of the sorghum. The samples were chopped, dried at 110°F. in a forced air, gas heated forage drier, coarsely ground through a hammer mill, and stored in plastic bags until fed in the digestion trials.

Crossbred wethers were the experimental animals for the series of conventional digestibility trials. In each trial, 24 animals were placed in metabolism stalls and randomly assigned six per sample to four forage samples. Seven-day preliminary and 7-day collection periods were used in all trials. Twice daily feed intake was established for each sheep during the first 5 days of the preliminary period and held constant for the remainder of that particular trial. Water was available free choice. Aliquot samples of the

[2]Mention of commercial trade names does not necessarily constitute endorsement of that particular product over other similar products.

forages were taken at each feeding; total excreta were weighed and sampled daily. Fecal samples were frozen and urine samples refrigerated until analyzed. Chemical analyses of forage, feces and urine were determined by A.O.A.C. (2) methods. Gross energy determinations were made using a Parr oxygen bomb, adiabatic calorimeter. Response criteria were forage component digestibility, energy utilization, nitrogen balance and total digestible nutrients. Statistical analyses of the data were by analysis of variance.

RESULTS AND DISCUSSION

Yield and Composition Data

Corn. The yield of whole plant corn was significantly higher ($P<.05$) at the early dent stage (III) than at the milk (II) or silk (I) stages (Table 1). In addition, yields were higher ($P<.05$) at the milk stage (II) than at the silk stage (I). Tissue analyses (Table 1) show that stage I had higher ($P<.05$) levels of nitrogen, potassium, calcium and magnesium than the other two stages. Content of these elements did not differ significantly between stages II and III. There was a decrease in the phosphorus levels of whole plant corn with each advanced stage of maturity, however these differences were not statistically significant.

TABLE 1. Yield and tissue analyses of whole plant corn harvested at three stages of maturity

Stage of maturity[1]	I	II	III
Days of growth	78	105	124
Dry matter, %	14	26	42
Dry matter yield, lb. per acre	4838[c]	11960[b]	15289[a]
Tissue analyses (dry matter basis), %			
Nitrogen	1.6242[a]	1.0123[b]	0.8127[b]
Phosphorus	0.1879[a]	0.1244[a]	0.1178[a]
Potassium	1.8062[a]	0.8834[b]	0.7187[b]
Calcium	0.3630[a]	0.2277[b]	0.2181[b]
Magnesium	0.3112[a]	0.1965[b]	0.1965[b]

[1]Stage I, silk; stage II, milk; stage III, early dent.

[a,b,c]Means within the same category having different superscripts are significantly different ($P<.05$).

TABLE 2. The effects of stage of maturity on yield and tissue analyses of forage sorghum for one-year growing period

Stage of maturity[1]	I	II	III
Dry matter, %	21	28	32
Dry matter yield, lb. per acre	27195[a]	28625[a]	28685[a]
Tissue analyses (dry matter basis), %			
Nitrogen	1.1907[a]	1.0165[b]	0.8527[c]
Phosphorus	0.1915[a]	0.1730[a]	0.1713[a]
Potassium	1.7020[a]	1.4021[a]	1.2587[b]
Calcium	0.2810[a]	0.2640[a]	0.1880[b]

[1]Stage I, heading; stage II, milk; stage III, dough.
[a,b,c]Means within the same category having different superscripts are significantly different ($P < .05$).

Sorghum. The total production of one-year growth of forage sorghum harvested at three stages of maturity did not differ significantly from one stage to the other (Table 2). Tissue chemical analyses show that nitrogen levels decreased ($P < .05$) with each progressive stage of maturity (Table 2). Phosphorus and potassium levels also declined with increasing maturity but these differences were not significant. Calcium levels of stages I and II were significantly ($P < .05$) higher than stage III.

Forage sorghum yields for each cutting at each stage of maturity during the one-year period are given in Table 3. These results indicate that yield of stage III decreased considerably after the original growth and remained lower for the following ratoons. The third stage of the original growth was very lightly infested with rust (*Puccinia purpurea* Cke) while stage III of the ratoon growths were very heavily infested thus reducing overall plant growth. Stages I and II invariably had light or medium infestation with this rust.

TABLE 3. Yield of original and ratoon growths of forage sorghum harvested at three stages of maturity[1]

	STAGE I		STAGE II		STAGE III	
Cutting	DM yield lb./acre	Days of growth	DM yield lb./acre	Days of growth	DM yield lb./acre	Days of growth
1st growth	2527	35	6766	56	15932	104
1st ratoon	7463	37	8634	64	4367	92
2nd ratoon	5064	47	4719	93	4748	115
3rd ratoon	4178	61	4051	91	3638[a]	97
4th ratoon	3076	85	4456[a]	84	—	—
5th ratoon	2619	68	—	—	—	—
6th ratoon	2268[a]	59	—	—	—	—

[1]Stage I, heading; stage II, milk; stage III, dough.
[a]Yield adjusted for one-year period of growth from planting date (5-19-65 to 5-19-66).

Temperature, rainfall and sunlight data are given in Table 4. Variations in these environmental factors during the year probably affected the rate of growth and the time required for the ratoons to reach the corresponding stages of maturity (Table 3). There was a close association between the solar energy received and days required for growth of the different forage sorghum crops. This suggests that solar energy data might be used as criteria in determining and predicting the number of days required for forage sorghum growth under specific sunlight, temperature and rainfall conditions in subtropical climates. The present forage sorghum planting has been maintained to obtain further data on solar energy, rainfall and temperature, and their effects upon yield and time required by forage sorghum ratoon crops to reach the specific stages of maturity.

TABLE 4. Weather data for growing period (May 1965 to May 1966) at the Waiakea Experiment Station

Year	Month	Rainfall inches	Mean temperature °F		Solar energy, daily average gm. cal./cm.^{2}
			Maximum	Minimum	
1965	May	22.43	79.0	64.0	314.2
	June	9.72	78.0	63.3	312.0
	July	9.01	77.8	62.2	377.1
	August	6.26	79.3	62.6	371.5
	September	7.08	80.7	62.6	376.5
	October	7.54	79.7	61.9	256.4
	November	21.97	76.1	62.3	197.5
	December	20.05	70.5	59.2	161.4
1966	January	16.13	71.6	58.2	212.5
	February	7.01	72.9	58.6	181.4
	March	7.20	74.6	58.8	263.6
	April	7.76	75.1	59.0	240.4
	May	6.49	78.9	62.3	316.1

Digestibility Data

Corn. The proximate compositions of whole plant corn at the three stages of maturity are presented in the first part of Table 5. Crude protein and crude fiber decreased from 9.4 percent and 35.2 percent to 5.5 percent and 22.7 percent at stages I and III, respectively. Nitrogen-free extract increased with advancing maturity from 47.3 percent at the first stage to 65.4 percent at the third stage. Similar changes in the content of these components with increased stages of maturity have been reported from other studies (3, 4, 5, 6, 9). These investigators observed that the ears constituted an increasing proportion of the total dry weight of the corn plant (up to 66 percent at maturity) with little or no vegetative growth after tasseling during the period of ear growth and maturation. The decreased crude fiber and increased nitrogen-free extract levels were primarily due to the lower proportion of leaves, stalks and husks to grain in the more mature plant. Johnson *et al.* (5) concluded that since the decreases in crude protein of the total plant could not be attributed solely to decreases in protein content of the leaves and stalks, a possible dilution of protein within the whole plant by other dry matter components might occur with increased maturity.

TABLE 5. Effects of stage of maturity on the proximate composition, digestibility, and per-acre digestible protein and total digestible nutrient yields of whole plant corn

Stage of maturity[1]	I	II	III
Chemical analyses (dry matter basis), %			
Organic matter	93.1	95.1	95.8
Ash	6.9	4.9	4.2
Crude protein	9.4	6.9	5.5
Ether extract	1.2	1.4	2.2
Crude fiber	35.2	27.8	22.7
N-free extract	47.3	59.0	65.4
Gross energy, kcal./gm. DM	4.436	4.342	4.297
Daily DM intake, gm.	462.1	513.0	414.1
Digestibility (dry matter basis), %			
Organic matter	61.2[b]	67.7[a]	71.7[a]
Crude protein	51.4[a,b]	53.3[a]	48.1[b]
Ether extract	44.8[c]	67.4[b]	78.3[a]
Crude fiber	64.6[a]	62.6[a]	62.2[a]
N-free extract	61.0[c]	71.8[b]	76.8[a]
Gross energy	58.0[b]	64.3[a]	68.2[a]
Digestible energy, kcal./gm. DM	2.575	2.794	2.932
Digestible protein (dry matter basis), %	4.8	3.7	2.6
Total digestible nutrients (dry matter basis), %	57.7	65.6	70.8
Yield, lb. per acre			
Digestible protein	232.1	442.5	397.5
Total digestible nutrients	2790.4	7845.8	10824.6

[1]Stage I, silk; stage II, milk; stage III, early dent.

[a,b,c]Means within the same category having different superscripts are significantly different ($P < .01$).

Corn digestibility data are given in Table 5. Organic matter and energy digestibility increased with each later maturity stage and increases were significant ($P < .01$) at stage II. Digestibility of nitrogen-free extract and ether extract increased ($P < .01$) with each extended stage of maturity. Crude fiber digestibility was not affected significantly by increased stages of maturity. Crude protein digestibility increased slightly at the second maturity stage and decreased ($P < .01$) when the growth interval was extended to stage III. Nitrogen balance was negative for all stages of maturity. This was probably a function of total protein content of the forage and total feed intake in addition to protein digestibility.

The digestibility results observed in the present experiment are in agreement with those reported from similar studies (3, 4, 6, 9) on the nutritive value of whole plant corn harvested at progressive stages of maturity. Johnson *et al.* (6) found that digestibility of the fibrous portions of the corn plant decreased only slightly from the silk to the dent stage. The reduction in crude fiber digestibility noted in the study reported herein was non-significant (64.6 to 62.2 percent) during the same advances in stage of maturity. Bryant *et al.* (3) also observed increased digestibility of dry matter, ether extract and nitrogen-free extract with extended stages of maturity, and concluded that the increased digestibility of these components resulted primarily because the ear constituted larger proportions of the total plant dry matter with each later maturity stage. These increases in digestibility and proportion of grain combined with the relatively constant crude fiber digestibility resulted in higher total digestible nutrients (TDN) with increased stages of maturity. Total digestible nutrients in the present study were 57.7 percent, 65.6 percent, and 70.8 percent at stages I, II and III, respectively. This closely agrees with the values reported by Bryant *et al.* (3) for comparable stages of maturity.

Yields of total digestible nutrients and digestible protein are given at the bottom of Table 5. The yield of TDN increased with each later stage of maturity. This was a function of both increased dry matter production (Table 1) and higher TDN content. Digestible protein yield increased at stage II and decreased somewhat at stage III. The decrease in percentage of digestible protein with each advanced stage of maturity probably was the major factor influencing digestible protein yields, and increases in dry matter yield did not fully compensate for these reductions. These results suggest that corn yielding the highest TDN may contain deficient levels of digestible protein.

Sorghum. The proximate composition of the original and first ratoon growth of forage sorghum harvested at various stages of maturity are given in Table 6. In both cuttings, crude protein levels were higher at stage I than at stages II and III, however overall protein levels tended to be lower in the ratoon growth. Crude fiber increased between stages I and II, then decreased at stage III in the original growth and successively decreased

TABLE 6. Effects of stage of maturity on the proximate composition of original and first ratoon growth of forage sorghum

Cutting Stage of maturity[1]	Original			First ratoon		
	I	II	III	I	II	III
Chemical analyses (dry matter basis), %						
Organic matter	91.5	92.8	95.3	94.8	94.1	92.4
Ash	8.5	7.2	4.7	5.2	5.9	7.6
Crude protein	12.5	8.0	4.6	8.5	4.8	5.5
Ether extract	1.7	1.1	1.6	0.9	1.4	1.6
Crude fiber	34.4	40.1	30.8	40.5	34.6	34.0
N-free extract	42.9	43.6	58.3	44.9	53.3	51.3
Gross energy, kcal./gm. DM	4.249	4.320	4.315	4.377	4.296	4.302

[1]Stage I, heading; stage II, milk; stage III, dough.

TABLE 7. Effects of stage of maturity on the digestibility of forage sorghum

Stage of maturity[1]	I	II	III
Digestibility (dry matter basis), %			
Organic matter	63.4^{a}	$58.5^{a,b}$	55.9^{b}
Crude protein	57.8^{a}	38.6^{b}	23.5^{c}
Ether extract	40.7^{c}	50.4^{b}	70.0^{a}
Crude fiber	69.2^{a}	61.4^{b}	51.5^{c}
N-free extract	60.4^{a}	58.2^{a}	60.7^{a}
Gross energy	59.7^{a}	53.5^{b}	51.8^{b}
Digestible energy, kcal./gm. DM	2.574	2.304	2.232
Digestible protein (dry matter basis), %	6.1	2.5	1.2
Total digestible nutrients (dry matter basis), %	59.7	55.4	53.8

[1]Stage I, heading; stage II, milk; stage III, dough.

[a,b,c]Means within the same category having different superscripts are significantly different ($P < .01$).

with each stage of maturity in the ratoon growth. Nitrogen-free extract levels tended to increase as the other two components decreased.

Digestibility of nutrient components in the forage sorghum at the three stages of maturity are summarized in Table 7. Organic matter digestibility decreased with each extended stage of maturity with a significant ($P < .01$) decrease between stages I and III. Gross energy digestibility followed similar trends. Digestibility of crude protein and crude fiber were reduced ($P < .01$) and ether extract digestibility increased ($P < .01$) with each later maturity stage. Nitrogen balance was negative with all treatments and was probably influenced by total feed intake as well as protein levels and digestibility. Nitrogen-free extract digestibility was not affected significantly by stage of maturity. The composition and digestibility changes noted in this study are similar to those observed by other investigators (1, 7, 8, 10).

Total digestible nutrients (TDN) were 59.7 percent, 55.4 percent and 53.8 percent at stages I, II and III, respectively, indicating that forage sorghum decreased in nutritive value as maturity progressed. The decrease in nutritive value was opposite that which was observed with the corn. This was probably because the seed constituted a lower percentage of the total plant dry matter in forage sorghum when compared with corn at advancing stages of maturity. These results indicate that the nutritive value of forage sorghum was higher at the earlier maturity stages.

TABLE 8. Digestibility of original and first ratoon growth of forage sorghum

Cutting	Original	First ratoon
Digestibility (dry matter basis), %		
Organic matter	62.5[a]	56.0[b]
Crude protein	43.6[a]	36.3[b]
Ether extract	53.7[a]	52.4[a]
Crude fiber	64.1[a]	57.3[b]
N-free extract	62.6[a]	57.0[b]
Gross energy	58.5[a]	51.5[b]
Digestible energy, kcal./gm. DM	2.510	2.230
Digestible protein (dry matter basis), %	3.7	2.3
Total digestible nutrients (dry matter basis), %	59.2	53.4

[a,b]Means within the same category having different superscripts are significantly different ($P < .01$).

The nutritive values of the original and first ratoon growths of forage sorghum are summarized in Table 8. Digestibility of all nutrients except ether extract was higher ($P < .01$) for the original growth than for the ratoon growth. Digestible protein and TDN were also higher in the original growth. These results are consistent with those reported by Reid *et al.* (8) who found that subsequent growths of forage sorghum were lower in nutritive value than the original growth.

The stage of maturity × cutting interactions were significant for the digestibility of all nutrients indicating that the effects of stage of maturity upon digestibility were influenced by cutting. The data presented in Table 9 give the digestibility of all components at each stage of maturity for both cuttings and illustrates these interactions. The interactions were expressed by changes in magnitude of response as well as direction of response when

TABLE 9. Effects of stage of maturity on the digestibility and per-acre digestible protein and total digestible nutrient yields of original and first ratoon growth of forage sorghum

Cutting	Original			First ratoon		
Stage of maturity[1]	I	II	III	I	II	III
Daily DM intake, gm.	308.2	317.3	566.4	345.0	411.1	406.3
Digestibility (dry matter basis), %						
Organic matter[a]	67.6	58.7	61.2	59.3	58.2	50.5
Crude protein[a]	63.4	47.0	20.4	52.1	30.1	26.7
Ether extract[a]	49.2	39.5	72.4	32.2	61.4	63.5
Crude fiber[b]	74.3	65.5	52.5	64.1	57.2	50.5
N-free extract[b]	64.0	55.1	68.7	56.9	61.3	52.7
Gross energy[a]	64.1	54.1	57.2	55.4	52.8	46.4
Digestible energy, kcal./gm. DM	2.722	2.338	2.470	2.426	2.270	1.994
Digestible protein (dry matter basis), %	7.9	3.8	0.9	4.4	1.4	1.5
Total digestible nutrients (dry matter basis), %	62.8	55.0	59.8	56.6	55.8	47.9
Yield, lb. per acre						
Digestible protein	199.7	257.1	143.4	328.4	120.9	65.5
Total digestible nutrients	1587.6	3721.3	9527.3	4224.0	4817.8	2091.8

[1]Stage I, heading; stage II, milk; stage III, dough.
[a]Significant ($P < .01$) cutting × stage of maturity interaction.
[b]Significant ($P < .05$) cutting × stage of maturity interaction.

the effects of stage of maturity were compared between the original and ratoon growths. Changes in direction of response were more frequently exhibited in the original growth which, perhaps, indicates that these variations contributed the larger portion of the variance component associated with the interactions.

Yields of digestible protein and total digestible nutrients at each stage of maturity for both the original and ratoon growth are given at the bottom of Table 9. The yield of TDN increased with each later stage of maturity in the original growth which was primarily a function of increased dry matter production (Table 3). Similar increases in TDN yield occurred in the ratoon growth except at the third stage. The decrease at stage III was influenced by the reduction in dry matter production at this stage, as previously mentioned. Yields of digestible protein were influenced both by total dry matter production and the decreases in levels of this nutrient at each extended stage of maturity. These results suggest that reduction in digestible protein levels should be a major consideration when evaluating the effects of stage of maturity on the nutritive value of forage sorghum. With the exception of stage I in the ratoon growth, yields of TDN and digestible protein per harvest were lower for the sorghum than for the corn (Table 5) at each respective stage of maturity.

SUMMARY AND CONCLUSIONS

Hybrid corn and forage sorghum were planted on newly cleared broken lava (*aa*) land to investigate the effects of stage of maturity on the yield, composition and nutritive value of these forages grown under high-rainfall, subtropical conditions. The stages of maturity were silk (I), milk (II) and early dent (III), and heading (I), milk (II) and dough (III) for the corn and sorghum, respectively. Ratoon growths in the sorghum were also harvested at the same stages of maturity as the original growth.

Dry matter (DM) yield was highest when whole plant corn was harvested at the early dent stage. This stage also produced the highest total protein per acre when compared to the silk or milk stages. The silk stage (I) was higher in percentage of protein than stages II or III. Digestibility of the energy components increased with each extended stage of maturity in whole plant corn. Crude protein digestibility increased slightly at stage II and decreased when the growth interval was extended to stage III. Total digestible nutrients (TDN) increased at each extended stage of maturity and were 57.7 percent, 65.6 percent, and 70.8 percent (DM basis) at stages I, II, III, respectively. Digestible protein levels (DM basis) decreased with each later growth interval and were 4.8 percent, 3.7 percent, and 2.6 percent at stages I, II and III, respectively. The results reported herein indicate that extended stages of maturity had similar effects upon yield, composition, and nutritive value of whole plant corn grown in high-rainfall, subtropical areas as that grown in temperate regions. The nutritive value per unit of dry matter was closely comparable between whole plant corn produced in subtropical and temperate zones.

There were no significant differences between the dry matter yields of the three stages of forage sorghum over a one-year production period. Total yearly protein production per acre decreased with each later stage of maturity in forage sorghum. Stage II appeared to be the most desirable for harvesting forage sorghum from the standpoint of yield, incidence of leaf rust and labor involved in harvesting. Digestibility of the nutrient components decreased in forage sorghum with each later stage of maturity. TDN (DM basis) was 59.7 percent, 55.4 percent, and 53.8 percent at stages I, II and III, respectively, indicating that forage sorghum decreased in nutritive value as maturity progressed. Digestible protein levels (DM basis) also declined with extended stages of maturity and were 6.1 percent, 2.5 percent, and 1.2 percent at stages I, II and III, respectively. The original forage sorghum growth contained higher levels of TDN (59.2 percent vs. 53.4 percent) and digestible protein (3.7 percent vs. 2.3 percent) than the first ratoon growth. As was observed with the corn, yield, composition, and nutritive value of forage sorghum produced in high-rainfall, subtropical regions were similarly affected by stage of maturity as that grown in temperate zones. Forage sorghum ratoon crops become a production consideration of greater importance in subtropical areas because growth and ratooning continue the year round.

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UNIVERSITY OF HAWAII
COLLEGE OF TROPICAL AGRICULTURE
HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII